Effects of Feeding Increased Amounts of Wet Corn Gluten Feed on Dairy Cow Metabolism and Milk Production

C. R. Mullins, K. N. Grigsby, D. E. Anderson, E. C. Titgemeyer, and B. J. Bradford

Summary

An experiment was conducted to evaluate the effects of feeding increasing dietary amounts of wet corn gluten feed (**WCGF**). Eight lactating Holstein cows were housed in a tie-stall facility and fed 1 of 4 diets containing 0, 11, 23, or 34% WCGF on a dry matter basis. To maintain similar nutrient concentrations, alfalfa hay, corn silage, corn grain, soybean meal, expeller soybean meal, and mineral supplements varied across diets. Feed intake, milk production, body weight, and body condition score were monitored, and effects of WCGF inclusion rate were assessed. Increasing the level of WCGF in the diet led to increased feed intake, milk production, and body condition. Concentrations of milk components did not differ among treatments; therefore, yield of energy-corrected milk and solids-corrected milk increased as well. In contrast, increasing dietary WCGF decreased efficiency of production and also decreased ruminal pH, possibly because treatments with greater proportions of WCGF had a decreased mean particle size. As expected, the decreased ruminal pH coincided with changes in ruminal volatile fatty acid concentrations. Furthermore, the rate of fiber digestion after 24 hours decreased when more WCGF was incorporated into diets. Results indicate that adding WCGF to dairy rations can increase energy-corrected milk yield, and this increase seems to be driven, at least in part, by an increase in feed intake.

Introduction

The large demand for cereal grains for purposes beyond feeding livestock has contributed to rising feed costs. Because many rations are formulated on a least-cost basis, researchers and producers are pressured to devise novel strategies to help keep feed costs in check. Recently, focus has turned to the use of milling coproducts, particularly wet corn gluten feed (**WCGF**). Wet corn gluten feed is a rapidly digestible non-forage source of fiber and protein. Feeding WCGF to dairy cattle can be a low-cost method of providing energy and nutrients needed for milk production.

Defining the optimum amount of WCGF to incorporate into a diet is complex because this substance interacts with other feed ingredients. Formulating diets to complement the characteristics of WCGF, rather than substituting WCGF for a single ingredient, will increase the likelihood of optimizing its use in lactation diets. The physically effective neutral detergent fiber (**peNDF**) value of WCGF is very low; therefore, sources of peNDF must be included when evaluating feedstuffs to complement WCGF. Rumination is stimulated when peNDF is provided, leading to longer chewing times, greater saliva production, and normal ruminal pH values. If the total mixed diet does not provide adequate peNDF, rumen health may be compromised and milk fat depression can occur.

The objective of this study was to feed increasing amounts of WCGF to lactating dairy cows and monitor effects on production traits. We also measured the effects of WCGF on the rumen environment and the rate of ruminal fiber digestion.

Experimental Procedures

Eight lactating cows averaging 90 days in milk were housed in a tie-stall facility and fed 1 of 4 diets that contained 0, 11, 23, or 34% WCGF (Sweet Bran; Cargill, Inc., Blair, NE) on a dry matter basis. Nutrient composition of the WCGF used in this study is shown in Table 1. This study was designed so each cow received all 4 treatment diets, allowing us to evaluate individual responses to diets. Alfalfa hay, corn silage, corn grain, soybean meal, expeller soybean meal, and mineral supplements varied among diets so that similar nutrient concentrations were maintained. Ingredients and nutrient compositions of diets are shown in Table 2.

Cows were fed a total mixed ration (**TMR**) twice daily, and amounts fed and refused were recorded daily for each cow during each of the four 28-day periods. Feed samples of individual ingredients were collected for analysis on days 25 to 28. Cows were milked thrice daily, and milk yield was recorded. Milk samples were collected from all milkings on days 25 to 28, and these samples were used to determine milk composition. Body weight and body condition score were measured at the beginning and end of each period. Particle size of the TMR and refusals were measured with the Penn State Particle Separator. Rumen samples and ruminal pH data were collected every 9 hours from days 26 to 28 so that 8 samples were collected from each cow during each period, representing every 3 hours of a 24-hour period to account for diurnal variation. Soybean hulls were incubated in Dacron bags suspended in the rumen on days 21 to 24 of each period to assess dietary effects on rate of ruminal fiber digestion.

Results and Discussion

Feed Intake and Milk Production

As the inclusion rate of WCGF increased, feed intake increased ($P = 0.03$) from 58.9 to 65.5 lb/day (Table 3). Because intake is influenced by specific gravity of the feedstuffs, particle size, and rate of fermentation, it is no surprise that intake increased in diets with greater concentrations of WCGF.

Milk yield increased ($P = 0.007$) from 81.1 to 85.8 lb/day as greater proportions of WCGF were offered (Table 3); however, concentrations of milk components were not affected ($P > 0.13$; Table 4). Because of the increases in milk yield, there were greater yields of fat, protein, and lactose as WCGF was added (Table 4). The increases in milk and milk component yields from increased WCGF led to greater ($P < 0.01$) solids-corrected milk and energy-corrected milk production (Table 3). The total energy being used for productivity, which includes production of milk and changes in body condition score, increased as WCGF inclusion rate increased ($P < 0.001$; Figure 1). This energy increase is not surprising because feed intake was greater for these cows, which likely resulted in greater consumption of energy. Feed efficiency, measured as energy-corrected milk yield divided by intake, declined ($P = 0.007$) as more WCGF was added (Table 3). Treatments did not affect energy efficiency, measured as total net energy for productive use over intake. Therefore, when milk production efficiency decreased in diets with greater WCGF, energy was not lost, rather it contributed to increased body condition. Body condition score increased ($P < 0.02$) as greater proportions of WCGF were fed (Table 3). Body weight change was not affected by treatment and did not correspond with changes noted in body condition, likely because diets led to differences in gut fill, which would affect measured weight change.

Substituting WCGF for portions of corn silage, alfalfa, corn grain, and soybean meal kept dietary neutral detergent fiber (**NDF**) values similar (≈30%), but the effectiveness of that fiber can be questioned. Table 5 shows the particle size data of the TMR and orts. All 4 diets had a relatively small mean particle size. In all diets, the mean percentage of particles >19 mm was about 3%. This proportion of particle size is small, but it is within current recommendations for a lactating cow TMR. In contrast, according to these same guidelines, all 4 treatment diets contained an insufficient proportion of particles between 8 and 19 mm. Comparing particle sizes of the refusals with that of the TMR showed no differences in the 3 fractions tested, suggesting that cows did not sort feed components.

An adequate supply of long particles is necessary for healthy rumen function and maintenance of ruminal pH. Diets lacking long particles are generally more fermentable, which can lead to greater acid production; this is a potential explanation for the decrease ($P < 0.001$) in ruminal pH as WCGF was added to the diet (Table 6). Excessive acid production is often attributed to starch in dairy rations; however, the diet with the lowest pH also had the lowest starch concentration, suggesting that acid production may not be related to dietary starch content. In contrast, highly fermentable fiber (i.e., WCGF) also replaced less-fermentable forage fiber, so total diet fermentability may have increased with WCGF additions. Even though adding WCGF depressed ruminal pH, milk fat production was not adversely affected. This suggests the diet with 34% WCGF still provided enough effective fiber to maintain rumen function and promote ruminal biohydrogenation.

Ruminal Metabolism

Measures of ruminal fermentation are presented in Table 6. As expected, the lower pH observed as WCGF was added coincided with decreased ($P < 0.001$) ruminal acetate and isovalerate concentrations and increased ($P < 0.001$) propionate and valerate concentrations. Differences in diet particle size or ruminal fiber digestibility may account for these effects. Quadratic effects were detected for concentrations of total volatile fatty acids (**VFA**) (trend: $P < 0.09$) and ammonia ($P < 0.01$); cows fed 0 and 34% WCGF tended to have greater overall VFA and ammonia concentrations. In general, this study shows that WCGF significantly affected the VFA profile.

Rate of Fiber Digestion

Soybean hulls have a highly digestible fiber fraction and minimal associative effects; therefore, they were used to measure rate of fiber digestion in the rumen as influenced by each diet. Digestibility of soybean hulls showed a significant diet by time interaction (Figure 2; $P < 0.001$). Increasing WCGF quadratically affected ($P < 0.001$) NDF disappearance at 24 hours (Table 6), showing the diet with 23% WCGF to have the lowest disappearance of soybean hull NDF. There was no correlation ($R^2 = 0.0002$) between pH and 24-hour NDF disappearance, suggesting that pH does not seem to be the primary cause of change in fiber digestion. It is unclear how increasing WCGF inclusion negatively affected rate of NDF digestion.

Results from this study demonstrate responses to WCGF that are consistent with recently published research. However, rather than indicating that WCGF improves the rumen environment for fiber-digesting bacteria, production responses to WCGF in this study seem to have been driven by increased feed intake. As a whole, adding WCGF to dairy rations will likely increase milk yield; however, this increase in production is driven, at least in part, by an increase in feed intake.

Table 1. Nutrient composition of wet corn gluten feed used in experiment[1]

Nutrient	% of dry matter	Standard deviation
Dry matter (% as-fed)	56.1	0.9
Crude protein	24.5	0.4
Neutral detergent fiber	35.3	1.1
Acid detergent fiber	11.0	0.9
Ether extract	2.3	0.2
Starch	11.2	0.5
Ash	5.8	0.4

[1] Samples collected on days 25 to 28 of all 4 periods.

Table 2. Ingredient and nutrient compositions (% of dry matter) of diets containing increasing amounts of wet corn gluten feed (WCGF)

	Dietary WCGF			
Item	0%	11%	23%	34%
Ingredient				
WCGF[1]	0.0	11.4	23.2	33.6
Corn silage	25.2	25.5	22.1	18.4
Alfalfa	24.4	24.6	21.2	17.7
Cottonseed	6.1	6.2	6.2	6.1
Corn grain	23.5	19.9	17.3	14.6
Soybean meal	8.6	4.9	2.2	2.2
Molasses	0.4	0.4	0.4	0.4
Expeller soybean meal	3.3	3.7	4.0	3.6
Soybean hulls	5.0	—	—	—
Limestone	1.00	1.08	1.28	1.36
Magnesium oxide	0.26	0.24	0.21	0.17
Micronutrient premix[2]	1.33	1.32	1.33	1.31
Nutrient				
Dry matter, % as fed	65.4	60.0	61.3	61.2
Crude protein (CP)	19.3	18.8	19.1	20.1
Rumen degradable protein, % of CP	63.5	65.3	63.9	66.6
Neutral detergent fiber	28.8	28.8	30.4	31.0
Starch	24.3	27.9	25.5	24.2
Non-fiber carbohydrate	39.1	40.9	38.6	37.6
Ether extract	3.4	3.3	3.6	3.6
Ash	9.4	8.3	8.3	7.7

[1] Wet corn gluten feed; Sweet Bran, Cargill, Inc., Blair, NE.
[2] Premix consists of 61.0% sodium bicarbonate, 27.3% trace mineral salt, 3.90% 4-plex, 3.90% Se premix, 2.60% vitamin E, 1.30% vitamin A, and 0.21% vitamin D.

Table 3. Effects of dietary wet corn gluten feed (WCGF) on performance of lactating cows

	Dietary WCGF[1]					*P* value	
Item	0%	11%	23%	34%	SEM	Linear	Quadratic
Dry matter intake, lb/day	58.9	57.1	64.6	65.5	3.4	0.03	0.55
Milk, lb/day	81.1	81.6	88.4	85.8	5.7	0.007	0.28
Solids-corrected milk, lb/day	77.6	78.7	84.9	82.0	5.6	0.01	0.19
Energy-corrected milk, lb/day	84.2	85.5	91.9	89.1	6.2	0.01	0.19
Efficiency[1]	1.44	1.50	1.34	1.29	0.06	0.007	0.20
Body weight change, lb/28 days	100	31	20	65	38.8	0.65	0.73
Body condition score change/28 days	-0.02	0.09	0.15	0.25	0.07	0.02	0.92

[1] Measured as energy-corrected milk divided by feed intake.

Table 4. Effects of dietary wet corn gluten feed (WCGF) on milk components

	Dietary WCGF					*P* value	
	0%	11%	23%	34%	SEM	Linear	Quadratic
Milk fat, %	3.65	3.76	3.72	3.67	0.11	0.93	0.23
Milk protein, %	3.02	3.07	3.05	3.11	0.08	0.13	0.80
Milk lactose, %	5.02	5.00	5.03	5.01	0.03	0.94	0.96
Somatic cell count,[1] 1000/mL	40.6	64.1	31.9	50.2	14.8	0.96	0.87
Urea nitrogen, mg/dL	17.2	16.3	16.3	17.3	0.90	0.83	0.08
Yield, lb/day							
Milk fat	3.02	3.06	3.28	3.17	0.24	0.06	0.21
Milk protein	2.45	2.51	2.67	2.67	0.18	0.01	0.49
Milk lactose	4.18	4.08	4.45	4.30	0.29	0.01	0.32

[1] Three outliers were removed.

Table 5. Effects of dietary wet corn gluten feed (WCGF) on particle size of diets and feed refusals (% as-fed basis)[1]

		Dietary WCGF			
Sample	Size	0%	11%	23%	34%
Total mixed ration	>19 mm	3.9[a]	3.3[ab]	3.0[ab]	2.4[b]
	19 to 8 mm	29.6[a]	29.6[a]	27.2[b]	24.2[c]
	<8 mm	66.6[a]	67.2[a]	69.9[b]	73.4[c]
Feed refusals[2]	>19 mm	4.2	5.1	3.9	1.5
	19 to 8 mm[3]	27.4	30.0	30.6	23.7
	<8 mm[3]	70.6	64.9	65.5	74.7

[abc] Means within row without a common superscript letter differ ($P < 0.05$).

[1] Measured using a 3-compartment Penn State Particle Separator.

[2] No significant differences were detected ($P > 0.15$) between the total mixed ration and feed refusals for each fraction across dietary treatments.

[3] One outlier was removed.

Table 6. Effects of dietary wet corn gluten feed (WCGF) on rumen environment

	Dietary WCGF					P value	
Item	0%	11%	23%	34%	SEM	Linear	Quadratic
Total VFA[1], m*M*	168.6	163.8	160.1	165.0	4.5	0.26	0.09
Acetate, m*M*	97.2	90.6	87.1	84.6	2.4	<0.001	0.15
Propionate, m*M*	34.4	37.8	36.8	43.1	1.3	<0.001	0.15
Butyrate, m*M*	25.9	26.0	25.3	26.9	1.1	0.32	0.43
Isobutyrate, m*M*	2.10	2.11	2.08	2.16	0.08	0.59	0.60
Valerate, m*M*	4.38	4.76	4.90	5.84	0.26	<0.001	0.02
Isovalerate, m*M*	3.45	3.36	3.11	2.56	0.31	0.001	0.16
Ammonia, m*M*	16.2	13.1	12.9	15.7	1.2	0.69	0.01
Ruminal pH	6.18	6.12	6.14	5.91	0.06	0.001	0.07
24-hour in situ NDF[2] disappearance, %	58.0	48.0	37.6	46.4	2.64	<0.001	<0.001

[1] Volatile fatty acid.
[2] Neutral detergent fiber.

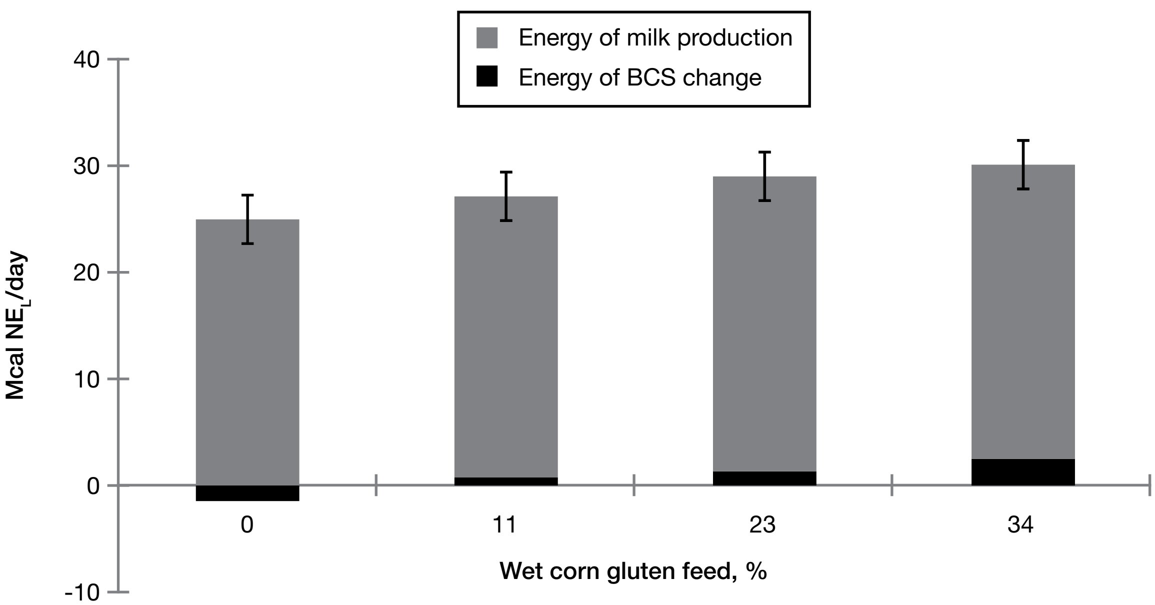

Figure 1. Total energy partitioned to milk production and body condition score (BCS) change in cows fed increasing amounts of WCGF.
As WCGF was added, total productive energy increased ($P < 0.001$) linearly. Body condition score loss was assigned an energetic value of 368 Mcal/unit, and BCS gain was assigned 459 Mcal/unit (National Research Council, 2001, Natl. Acad. Sci., Washington, DC.). Milk energy was calculated according to the equation: [Milk energy = (41.63 × % fat) + (24.13 × % protein) + (21.60 × % lactose) – 11.72].

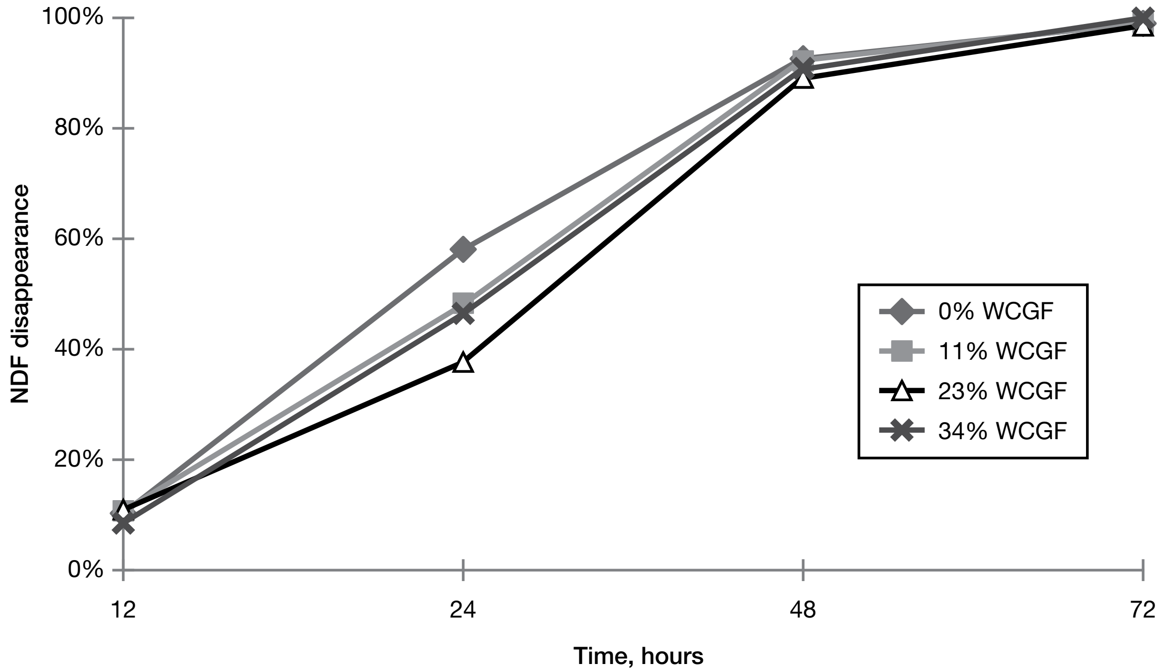

Figure 2. In situ neutral detergent fiber (NDF) disappearance of soybean hulls in diets with increasing amounts of wet corn gluten feed (WCGF) measured over a 72-hour period. A time by treatment interaction ($P < 0.001$) was detected for dry matter digestibility. After 24 hours of ruminal degradation, a quadratic effect ($P < 0.001$) was detected for in situ NDF disappearance of soybean hulls. The quadratic response was driven by lower disappearance in the diet with 23% WCGF.